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CO_2 emissions in China: analysis based on factor decomposition method

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Abstract

This paper reports on factor decomposition for historical CO_2 emissions volume and carbon intensity in China from 1980–2010 using the logarithmic mean divisia index method. The results show that total economic output was always the dominant factor accounting for the growth of CO_2 emissions, and it was also the most stable factor. Energy intensity promoted the carbon emissions reduction factor during every period, although it contributed very little during the 10th Five Year Plan (FYP). Industrial structure promoted carbon emissions reduction during 6th, 7th, 9th, and 11th FYPs, but the contribution was relatively small. During the 8th and 10th FYPs, the structure effect became a contributing factor to the growth of carbon emissions. As for carbon intensity, industrial structure promoted a lower carbon intensity factor during 6th, 7th, 9th, and 11th FYPs, but the contribution was relatively small. During other periods, industrial structure became a contributing factor to the growth of carbon intensity. Based on these results, the key to energy conservation in the future lies in industrial structure adjustment, especially the development of the tertiary industry.

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Key words: CO_2 emissions, carbon industry, industrial structural change, logarithmic mean divisia index (LMDI)

1. Introduction

Keeping the increase in global mean temperature rise due to climate change to 2 °C will require carbon emissions to peak in the near future. According to International Energy Agency statistics, China's CO_2 emissions have been growing at a fast pace since the inception of China's reform and opening up. China's

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CO_2 emissions surpassed those of the United States, previously the world's largest emitter, in 2007. At present, China's rate of industrialization and urbanization is increasing, and CO_2 emissions will continue growing into the foreseeable future. Thus, China's future CO_2 emission controls will be critically important for the global response to climate change. What are the factors affecting China's increasing carbon emissions? Generally speaking, these factors fall into various technical and structural categories, as described later in this paper. To formulate China's future energy and CO_2 emissions reduction policies, the factors leading to China's increasing carbon emissions must be understood through careful scientific analysis.

Current factor decomposition research addresses the factors contributing to the growth of carbon emissions but fails focus on the whole system. Instead, this research analyzes only the impact of industrial structure or eventual demand structure on carbon emissions or emissions intensity while not addressing the overall system. This paper reports on systematic research concerning the impact of industrial structure changes on China's carbon emissions and emissions intensity during the 30 years (1980–2010) after China's reform and opening up. Our research uses the logarithmic mean divisia index (LMDI) method to set up decomposition models for carbon emissions and emissions intensity, followed by a comprehensive comparison and analysis, and finally, an overall evaluation of the impact of industrial structure changes on China's carbon emissions.

2. CO_2 emissions and carbon intensity in China

The CO_2 emissions volume and carbon intensity of three Chinese industrial categories from 1980–2010 are shown in Fig. 1. Over this time, China's CO_2 emissions have continued to grow, and the emission characteristics can generally be divided into the following three stages: (1) From 1980–1996, the emissions volume maintained a steady growth rate of 5.64% per year, while the year-to-year increase in emissions volume for the secondary and tertiary industry categories remained small. (2) From 1996–2003, the emissions volume growth rate dramatically declined by 2.51% per year, the emissions volume of the secondary industry remained constant, and emissions volume for the tertiary industry experienced small year-to-year growth. (3) From 2003–2010, the emissions volume increased dramatically at a rate of 9.79% per year, and both secondary and tertiary industry categories experienced large year-to-year growth. Over the 30-year period, the emissions volume for the primary industry remained almost constant, the emissions volume of the tertiary industry showed a steady increase, and the emissions volume of the secondary industry closely tracked the overall emissions growth pattern. This trend proves that the secondary industry was most influential in determining the emissions growth rate, and therefore, it is appropriate that it become the focus of national industrial restructuring.

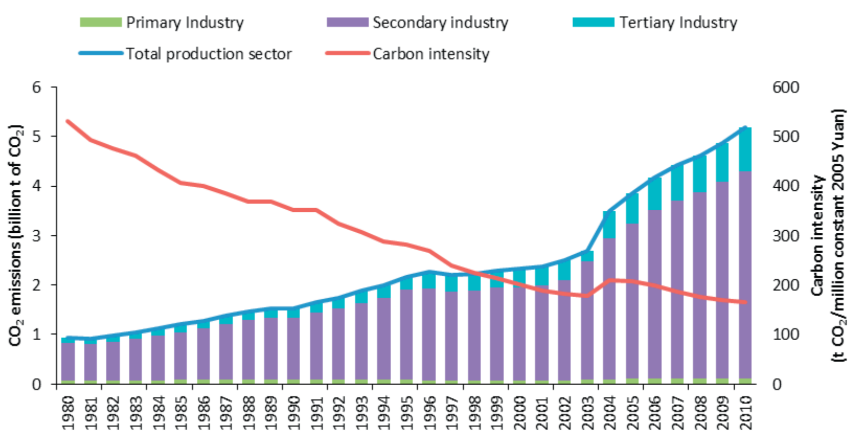

Fig 1. China's production sector CO_2 emissions and carbon intensity.

3. Methodology and data

As derived from index decomposition analysis, the log mean divisia index (LMDI) decomposition method has several advantages, including thorough decomposition, no deviation, uniqueness of results, and easy use. Our research followed the guide to LMDI established by Ang (2005).

3.1 LMDI decomposition model

Based on existing research results, our research applied the following CO_2 emissions volume equation:

$$C = \sum_{ij} C_{ij} = \sum_{ij} Q \frac{Q_i}{Q} \frac{E_i}{Q_i} \frac{E_{ij}}{E_i} \frac{C_{ij}}{E_{ij}} = \sum_{ij} Q S_i I_i M_{ij} U_{ij} \tag{1}$$

Similarly, we used the following CO_2 emissions intensity equation:

$$G = \frac{\sum_{ij} C_{ij}}{Q} = \sum_{ij} \frac{Q_i}{Q} \frac{E_i}{Q_i} \frac{E_{ij}}{E_i} \frac{C_{ij}}{E_{ij}} = \sum_{ij} S_i I_i M_{ij} U_{ij} \tag{2}$$

Applying the LMDI method, we decomposed the increase in carbon emissions volume into four components (economic aggregate effect, industrial structure effect, energy consumption intensity effect, and energy consumption structure effect), as follows:

$$\nabla C_{tot} = C^T - C^0 = \nabla C_{act} + \nabla C_{str} + \nabla C_{\text{int}} + \nabla C_{mix} + \nabla C_{emf} \tag{3}$$

Similarly, we decomposed the increase of carbon emissions intensity into three components (industrial structure effect, energy intensity effect, and energy structure effect), as follows:

$$\nabla G_{tot} = \nabla C_{str} + \nabla C_{\text{int}} + \nabla C_{mix} + \nabla C_{emf} \tag{4}$$

where ∇C_{emf} is the variation effect of the carbon emissions factor and is usually taken as zero.

3.2 Data source

We further divided the secondary industry category into light industry, heavy industry, and architecture industry, in accordance with the Dividing Method for the Light Industry and the Heavy Industry released by the National Bureau of Statistics in May 2012.

All economic data used in our research were obtained from the China Statistical Yearbook. Although the yearbook does not directly provide increase values for light and heavy industries, it presents their output values for each year. Using these data, we calculated increase values by multiplying the proportion of the output values for the light and heavy industries by the total industrial increase value. In doing so, we assumed that the percentage of increase value for the light and heavy industries was the same as their output value percentages. All economic data were adjusted to constant 2005 yuan.

All of the energy data in this paper are for final energy consumption. To facilitate our statistical calculations, we integrated energy into six categories (coal aggregate, coke, oil product aggregate, natural gas, thermal power, and electrical power), and each category was converted into standard coal according to the Yearbook attachment: *Referential coefficients for converting energies into standard coal*. The final energy consumption data for the three industry categories were obtained from the Yearbook's China Energy Balance Table.

4. Result and discussion

4.1 CO_2 emissions change analysis

The results of the LMDI model are shown in Fig. 2. Overall, the CO_2 emissions growth was 4242.36 million t from 1980–2010, which was mainly due to the change in total growth and energy consumption intensity. The results show that the growth rates attributed to the four effects were 161.61% (total growth effect), 1.83% (industrial structure effect), −66.48% (energy consumption intensity effect), and 3.04% (energy consumption structure effect). From year to year, total growth effect was always the dominant factor promoting the growth of CO_2 emissions, and it was also the most stable factor. Energy consumption intensity effect was always the dominant factor promoting the decline of CO_2 emissions, except for 1988 and 2003. Energy intensity in 2003, representing the most significant factor contributing to the growth of carbon emissions, was linked with China's accession to the World Trade Organization (WTO) and subsequent growth of energy-intensive industries. The contribution of the industry structure effect was relatively small, and its direction varied by year.

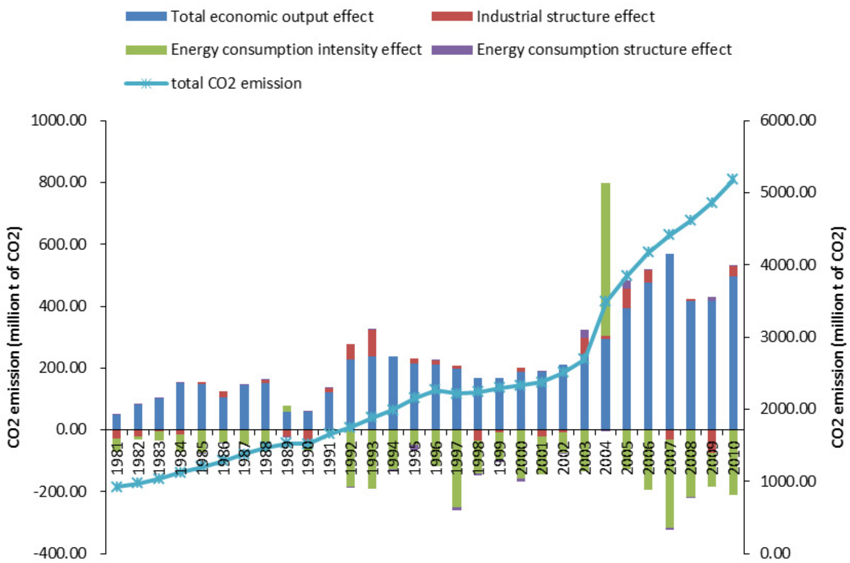

Fig 2. Factor decomposition of CO_2 emissions growth from 1980–2010.

4.2 Carbon intensity analysis

More results of the LMDI model are shown in Fig 3. Overall, the carbon intensity decline was 366.8 t CO_2/million constant 2005 yuan from 1980–2010, which was mainly due to the change in the energy consumption intensity effect. The results show that the contributions of the three effects were −1.06% (industrial structure effect), 96.54% (energy consumption intensity effect), and 4.53% (energy consumption structure effect). China's carbon intensity fell from 1980–2003, but suddenly increased in 2004, before falling again. The increase in 2004 was associated with the rapid growth of high energy-consuming industries after China's accession to the WTO. The impact of industrial structure on carbon intensity change was relatively large in 1980, 1981, 1991, and 1992, with the former 2 years exhibiting a decline in carbon intensity and the latter 2 years exhibiting growth in carbon intensity. For other years, the effects were relatively small and were both positive and negative. The energy intensity effect was usually a major factor promoting the reduction of carbon emissions intensity, but in 1988 and 2003 it contributed to the growth of carbon emissions intensity, and in 2003 energy intensity of was the only significant factor promoting growth in carbon emissions intensity. The energy structure effect generally promoted energy intensity of the carbon emissions reduction, but the effect was very small, reflecting to some extent China’s resource endowments and the slow optimizing of energy structure.

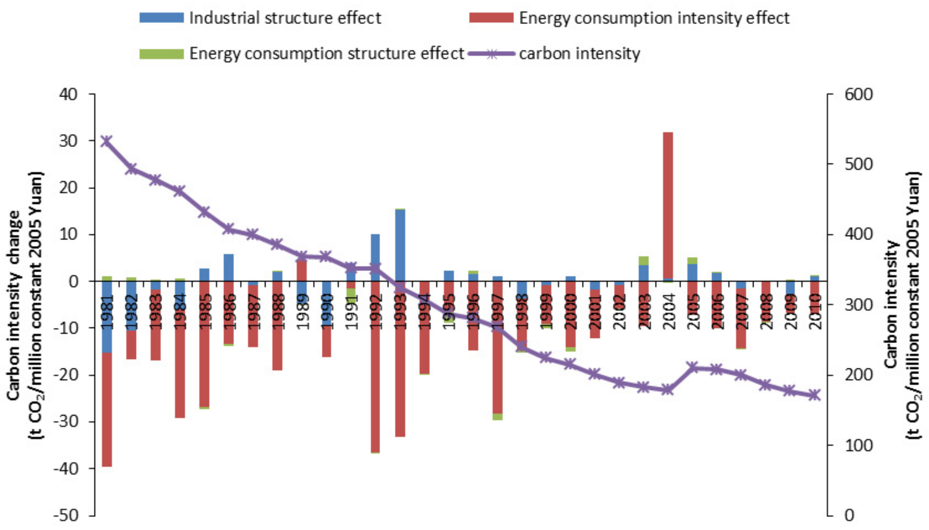

Fig 3. Factor decomposition of carbon intensity growth from 1980–2010.

5. Conclusion

With economic development in China over the past 30 years of reform and opening up, the proportion of primary industry value added gradually decreased, whereas the proportion of second and tertiary industry value added gradually increased. These observations are consistent with the general rules of evolution of industrial structure, where changes occur in a rationalization direction (i.e., reflecting an increase in total output and profits of the national economy). China has entered the latter stages of mid-industrialization, which means that the proportion of secondary industry will peak quickly, gradually shifting from the secondary industry to the tertiary industry, in full compliance with internal economic development law.

During the past 30 years, the total economic output effect was always the dominant factor promoting the growth of CO_2 emissions, and it was also the most stable factor. Energy intensity promoted the carbon emissions reduction factor during each period, but the contribution rate was small during the 10th FYP. This is explained by the proportion of energy-intensive industries initially increasing significantly, but then increasing more slowly after China entered the WTO, so that the energy intensity effects canceled each other out.

Also during the past 30 years, the average annual declining rate of emissions intensity reached 3.71%. This observation is consistent with the rate of decline in developed countries, indicating that the effectiveness of China's energy intensity reduction was significant. At the same time, the progress of technology contributed more to this declining rate, with a smaller contribution from industrial restructuring.

The gap between China's current technology level and that of developed countries is gradually decreasing, although the gap between the industrial structures is large. Thus, adjustments to China's industrial structures are important to economic growth and to reducing future energy demand and CO_2 emissions. The tertiary industry value added, which increased by 1%, will have a larger impact than the secondary industry, while the CO_2 emissions intensity of tertiary industry will be smaller. Therefore, the key to the energy conservation in the future lies in industrial structure evolution, especially the development of the tertiary industry.

Acknowledgments

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